

# Remote Sensing of Cloud Properties from the A-Train : Lessons Learned from 5 years of Coincident POLDER and MODIS Data in Light of Calipso/CloudSat Observations

*J. Riedi, S. Zeng, F. Thieuleux, N. Ferlay, F. Parol,  
C. Vanbause, L.C.-Labonne and C. Cornet*

*Laboratoire d'Optique Atmosphérique, Université des Sciences et Technologies de Lille*

*S. Platnick, M. King and the MODIS Cloud team at NASA/GSFC*

# Introduction

**Rationale :** we study clouds because they are puzzling – Even if climate wasn't changing, we would still be studying them !

**Context :** merging POLDER and MODIS provides a unique way of looking at clouds combining multi-resolution, multi-spectral, multi-angle and multi-polarization observations

**Approach :** merging software was developed to

- process L1 data with synergistic algorithm
- provide L2 products on a common grid and format (hdf files)



# Introduction

**Past and ongoing studies :** Most activities have dealt with combining POLDER and MODIS to better characterize cloud properties, create new products and using Calipso/Cloudsat for validation.

**Cloud fraction**

Parol et al (poster)

**Cloud phase**

Zeng et al (poster) + this talk

**Ice cloud microphysics**

Zhang et al (2009)

**Liquid cloud microphysics**

Bréon and Doutriaux (2005)

**Cloud optical thickness**

Cornet et al (poster)

**Cloud vertical structure**

Ferlay et al (poster)

**Aerosols above clouds**

Waquet et al (poster)

**Arctic Aerosols/Clouds**

Tietze et al (poster)



# POLDER/MODIS cloud phase products against CALIOP observations

S. Zeng, Phd thesis 2010, J. Riedi, F. Parol, C. Cornet

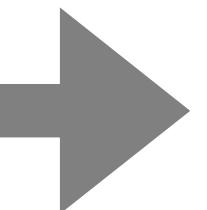
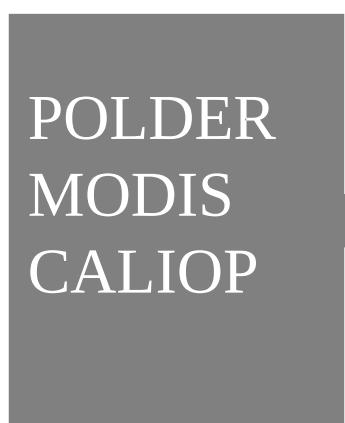
## 1- Products Validation

## 2 - Analysis of cloud top ice/liquid occurrence vs cloud top temperature



# Cloud phase as seen by POLDER, MODIS & CALIOP

Level 2 official data



## PM dataset:

(Level 2 of MODIS & POLDER data )

- resolution : 20 x 20km<sup>2</sup> on integerized sinusoidal grid
- MODIS averaged over POLDER pixel

## CALTRACK dataset:

(Level 2 of MODIS, POLDER & CALIOP data )

- resolution : 5km coincident CALIPSO cloud products

Products available through ICARE Data & Services Center  
<http://www.icare.univ-lille1.fr>

# Cloud phase as seen by POLDER, MODIS & CALIOP

We looked at the various combination of POLDER/MODIS phase with each instrument providing either ice, mixed or liquid phase

→ 9 POLDER/MODIS classes of cloud phase.

| POLDER<br>MODIS | ICE | LIQUID | MIXED |
|-----------------|-----|--------|-------|
| ICE             | OK  | !      | ?     |
| LIQUID          | !   | OK     | ?     |
| MIXED           | ?   | ?      | OK    |

Created statistics of the various combinations (geographic occurrences) and analyzed those in view of either :

- CALIOP vertical structure (single layer ? multilayer ? opaque ?)
- CALIOP observations using depolarization/backscatter space
- CALIOP cloud phase product

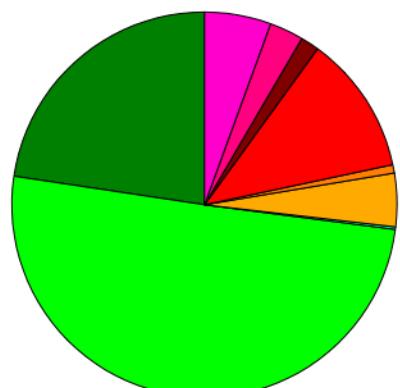
# MODIS / POLDER global match & mismatch

Data: PM dataset, 12/2007-11/2008, [90°S-90°N]

(a)

**POLDER/MODIS Swath  
All Case**

P(ice) M(ice):22.63%  
P(liq) M(liq):50.31%  
P(mix) M(mix):0.22%  
P(ice) M(liq):4.49%  
P(ice) M(mix):0.69%  
P(liq) M(ice):11.67%  
P(liq) M(mix):1.57%  
P(mix) M(ice):2.85%  
P(mix) M(liq):5.59%

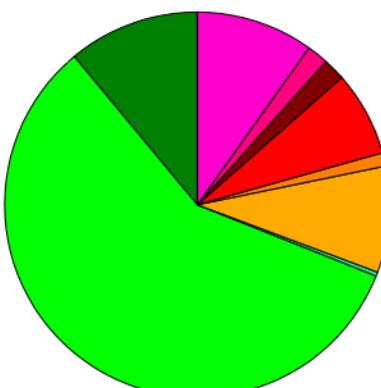


Total Num.:2.09E+08

(b)

**POLDER/MODIS Swath  
Broken Scene**

P(ice) M(ice):11.03%  
P(liq) M(liq):57.93%  
P(mix) M(mix):0.33%  
P(ice) M(liq):8.94%  
P(ice) M(mix):1.12%  
P(liq) M(ice):7.14%  
P(liq) M(mix):1.85%  
P(mix) M(ice):1.81%  
P(mix) M(liq):9.85%

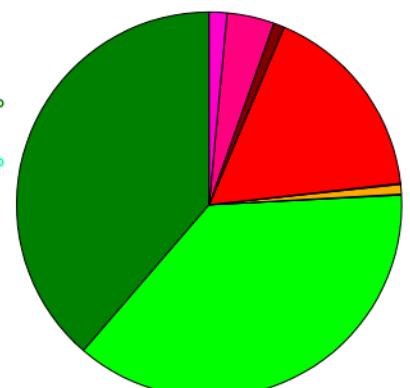


Total Num.:7.72E+07

(c)

**POLDER/MODIS Swath  
Overcast Scene**

P(ice) M(ice):38.67%  
P(liq) M(liq):37.13%  
P(mix) M(mix):0.07%  
P(ice) M(liq):0.81%  
P(ice) M(mix):0.09%  
P(liq) M(ice):16.86%  
P(liq) M(mix):0.92%  
P(mix) M(ice):3.95%  
P(mix) M(liq):1.49%

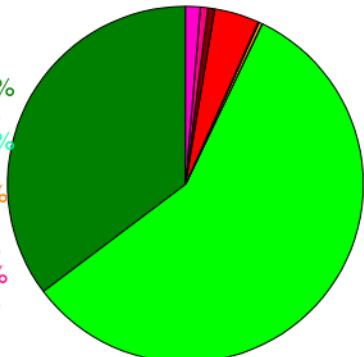


Total Num.:8.2E+07

(d)

**POLDER/MODIS Swath  
Overcast & Single Layer**

P(ice) M(ice):35.29%  
P(liq) M(liq):57.58%  
P(mix) M(mix):0.03%  
P(ice) M(liq):0.3%  
P(ice) M(mix):0.08%  
P(liq) M(ice):4.07%  
P(liq) M(mix):0.62%  
P(mix) M(ice):0.68%  
P(mix) M(liq):1.34%

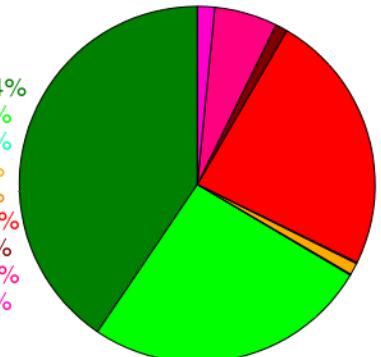


Total Num.:2.89E+07

(e)

**POLDER/MODIS Swath  
Overcast & Multiple Layer**

P(ice) M(ice):40.54%  
P(liq) M(liq):25.95%  
P(mix) M(mix):0.1%  
P(ice) M(liq):1.09%  
P(ice) M(mix):0.1%  
P(liq) M(ice):23.84%  
P(liq) M(mix):1.08%  
P(mix) M(ice):5.74%  
P(mix) M(liq):1.57%

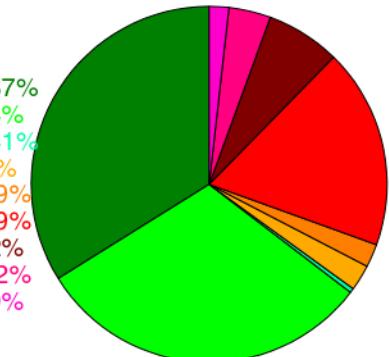


Total Num.:5.28E+07

(f)

**POLDER/MODIS Swath  
Over Snow**

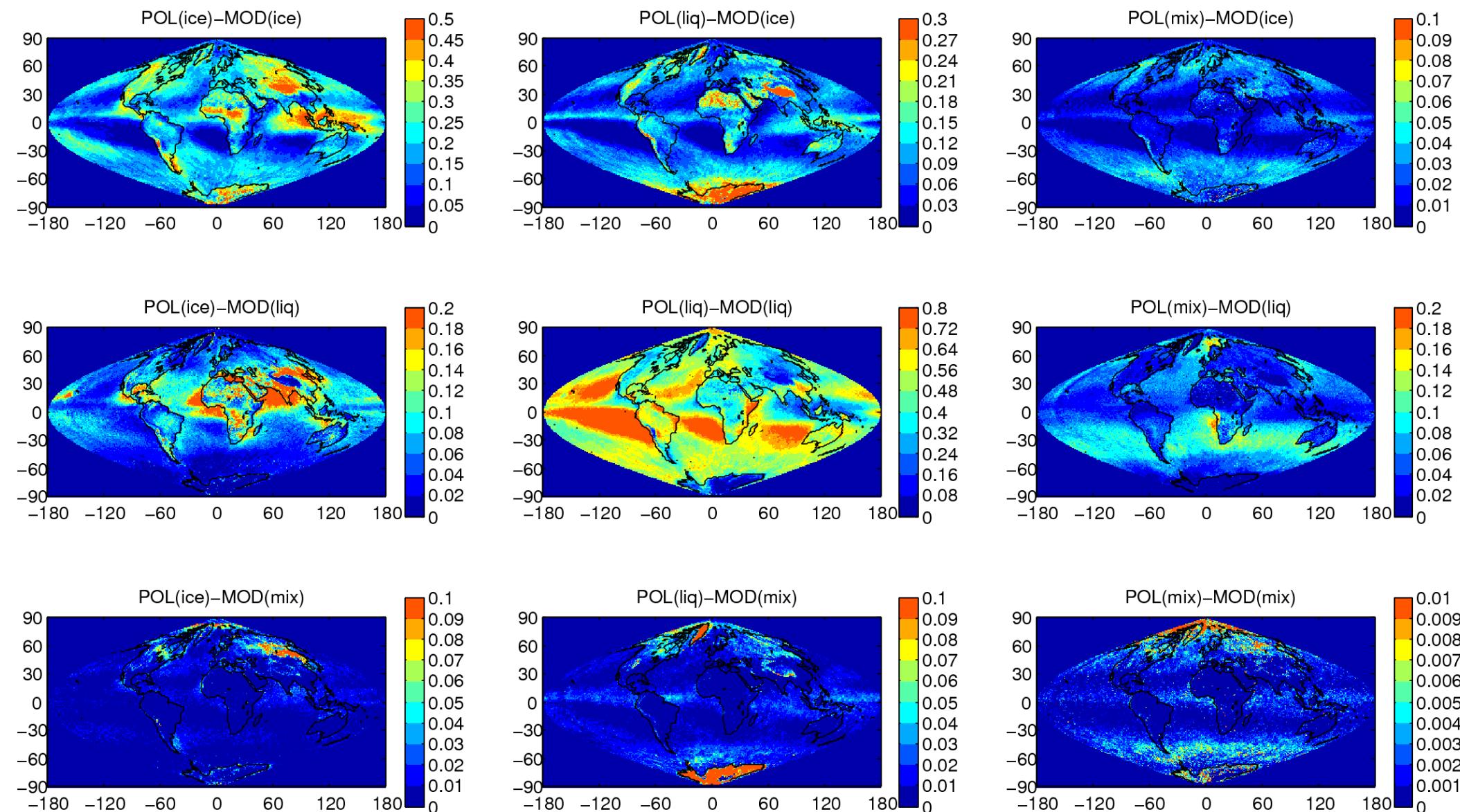
P(ice) M(ice):33.87%  
P(liq) M(liq):30.74%  
P(mix) M(mix):0.41%  
P(ice) M(liq):2.37%  
P(ice) M(mix):2.09%  
P(liq) M(ice):18.19%  
P(liq) M(mix):6.72%  
P(mix) M(ice):3.82%  
P(mix) M(liq):1.79%



Total Num.:1.37E+07

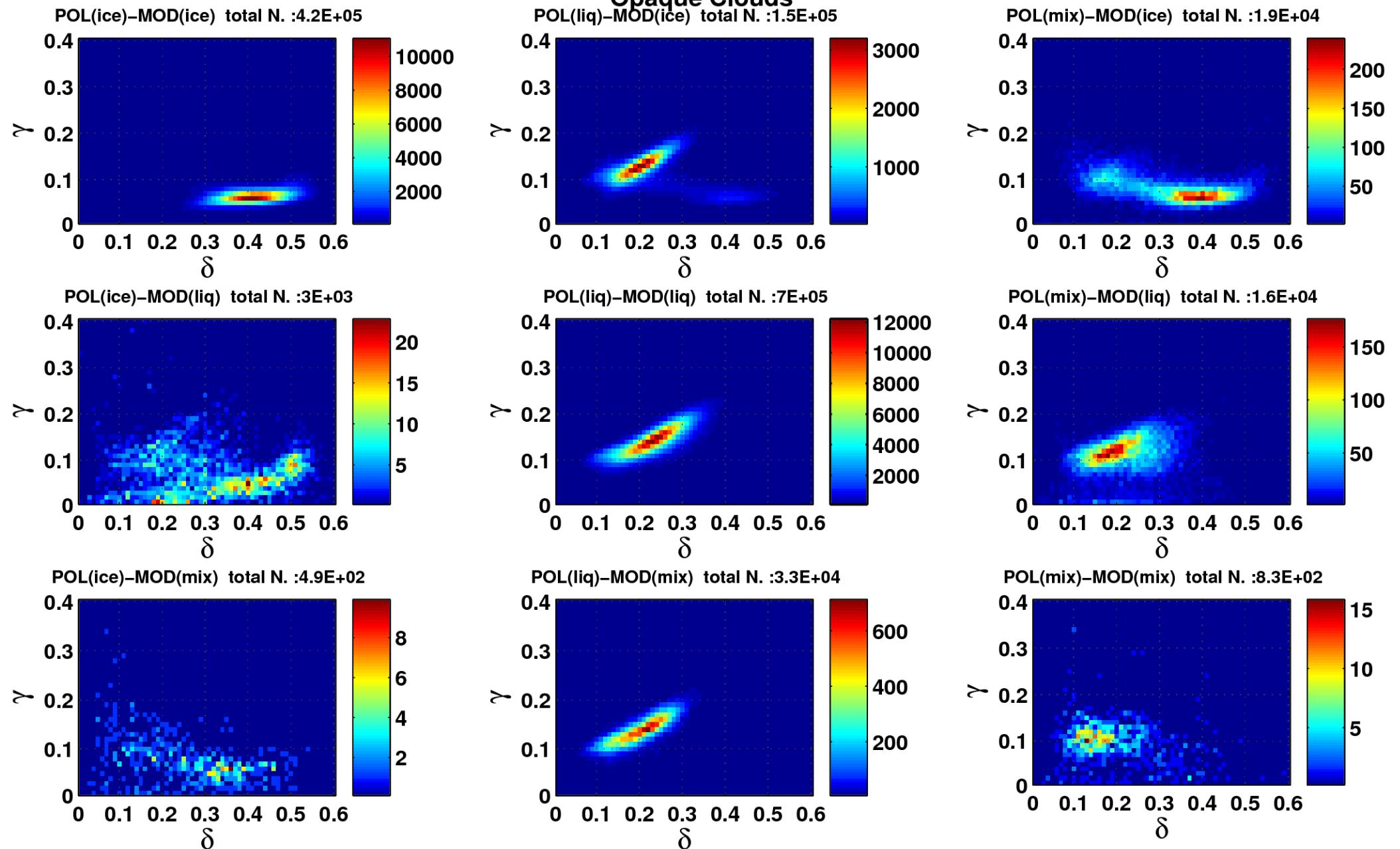
# Geographical Distributions of Phase Frequency

Data: PM dataset, 12/2007-11/2008, [90°S-90°N]



# POLDER/MODIS phase in CALIOP space

Data: CALTRACK dataset, 12/2007-11/2008, [90°S-90°N]

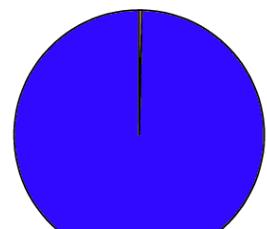


# POLDER/MODIS vs CALIOP phase product

Data: CALTRACK dataset, 12/2007-11/2008, [90°S-90°N]

**PHASE CASE: POLDER (ice) MODIS(ice)**

CALIOP liquid: < 1%

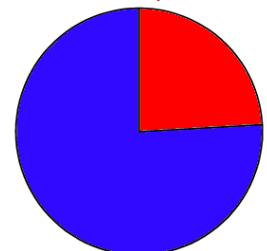


CALIOP ice: 100%

Total Number: 4.2E+05

**PHASE CASE: POLDER (ice) MODIS(liquid)**

CALIOP liquid: 24%

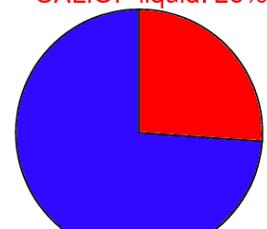


CALIOP ice: 76%

Total Number: 3E+03

**PHASE CASE: POLDER (ice) MODIS(mixed)**

CALIOP liquid: 26%

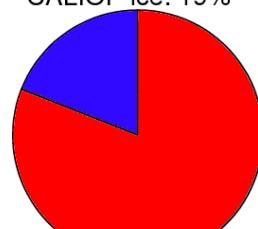


CALIOP ice: 74%

Total Number: 4.9E+02

**PHASE CASE: POLDER (liquid) MODIS(ice)**

CALIOP ice: 19%

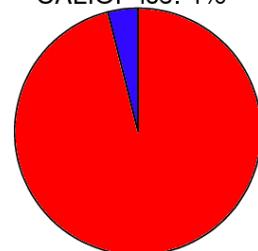


CALIOP liquid: 81%

Total Number: 1.5E+05

**PHASE CASE: POLDER (liquid) MODIS(liquid)**

CALIOP ice: 4%

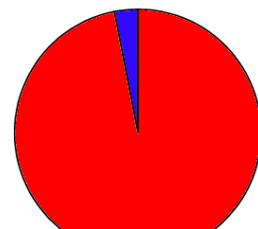


CALIOP liquid: 96%

Total Number: 7E+05

**PHASE CASE: POLDER (liquid) MODIS(mixed)**

CALIOP ice: 3%

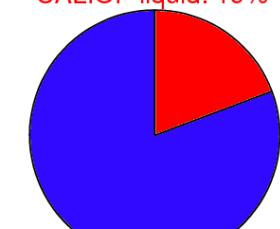


CALIOP liquid: 97%

Total Number: 3.3E+04

**PHASE CASE: POLDER (mixed) MODIS(ice)**

CALIOP liquid: 19%

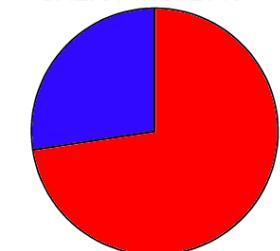


CALIOP ice: 81%

Total Number: 1.9E+04

**PHASE CASE: POLDER (mixed) MODIS(liquid)**

CALIOP ice: 27%

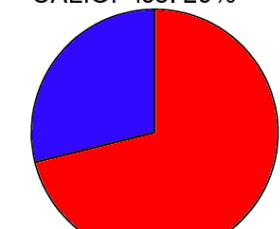


CALIOP liquid: 73%

Total Number: 1.6E+04

**PHASE CASE: POLDER (mixed) MODIS(mixed)**

CALIOP ice: 29%



CALIOP liquid: 71%

Total Number: 8.3E+02

## Observation of Cloud top phase dependency on temperature

**Rationale :** partitioning of condensed water in clouds between ice and liquid is critical for radiation, precipitation, dynamics, ... BUT there's still a wide spread in models regarding this partitioning.

**Context :** numerous studies show that supercooled water occurs very frequently and much more than currently represented in models.

Supercooled droplets at very low temperature : **Giraud et al, 2000** (POLDER and ATSR), **Riedi et al, 2001** (POLDER and radar/lidar ARM SGP site), **Hogan et al, 2003** (ground based lidar), **Choi et al, 2010** (MODIS + CALIOP), **Hu et al, 2010** (MODIS, IIR, CALIOP)

Impact of vertical motion : **Naud et al, 2006** (MODIS and NCEP-NCAR)

Model evaluation : **Doutriaux and Quaas, 2004** (LMDZ and POLDER), **Weidle and Wernli, 2008** (ERA40 and POLDER)

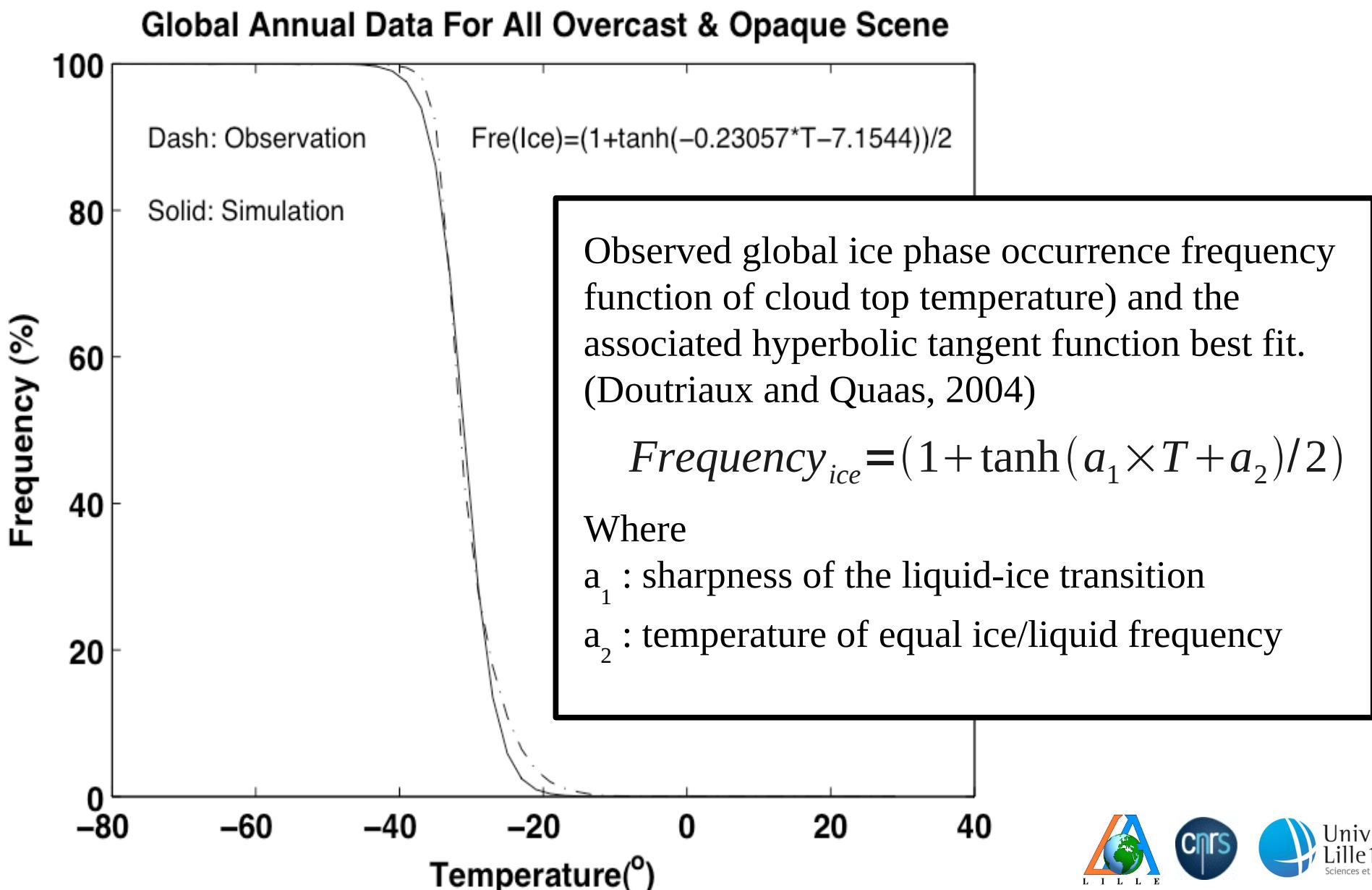
## Observation of Cloud top phase dependency on temperature

**Approach :** Use the high confidence dataset provided by combination of POLDER/MODIS products to look at the relation between cloud top phase and temperature and investigate this relation with respect to other microphysical, thermodynamical or dynamical parameters.

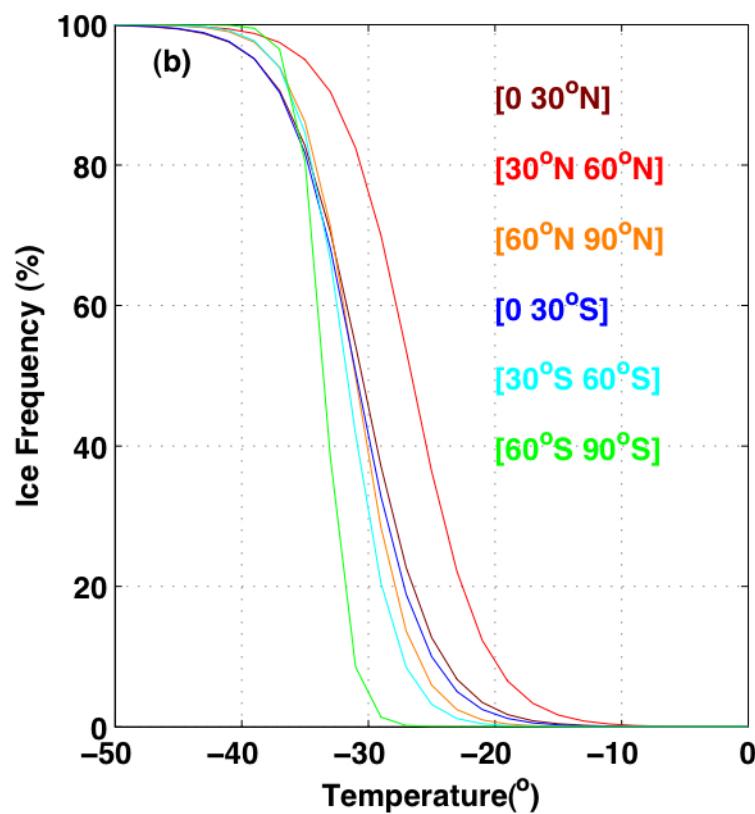
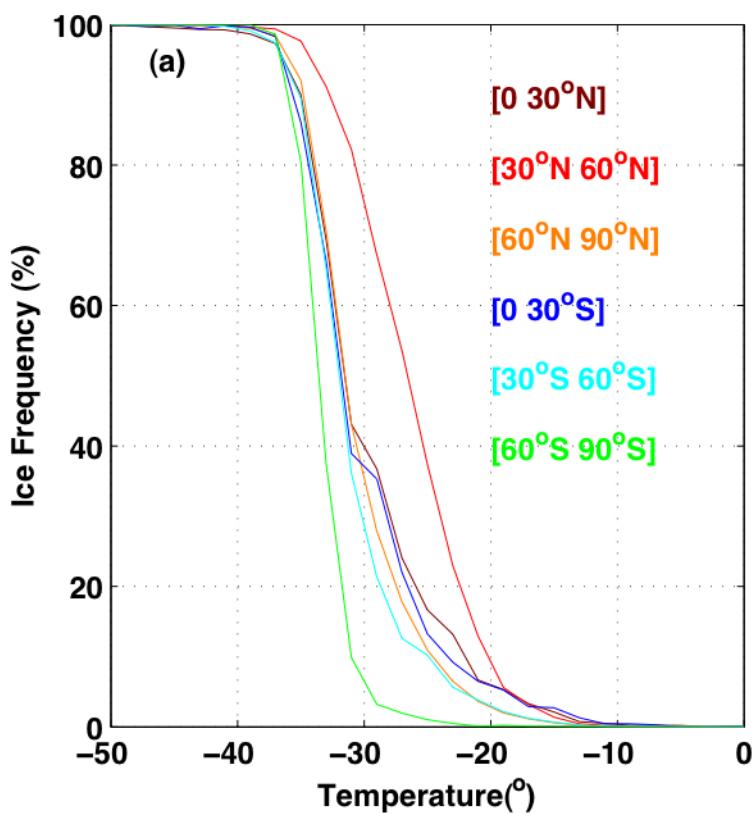
Under the assumption that clouds are observed at different stages of their life cycle, the observed statistical relation between ice/liquid fraction and temperature can provide insight into glaciation processes (especially regarding homogeneous vs heterogeneous nucleation).

All figures presented hereafter only show “observed” correlations  
→ **no causality is claimed at this stage of our studies**

## Observed Cloud top phase dependency on temperature

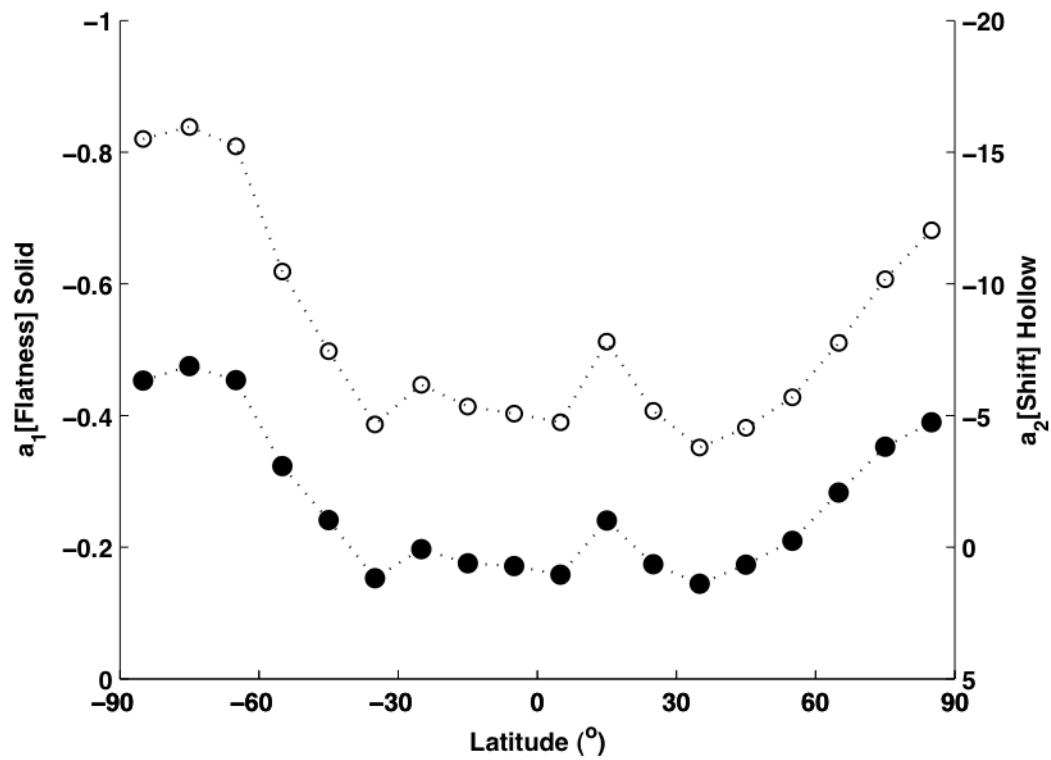
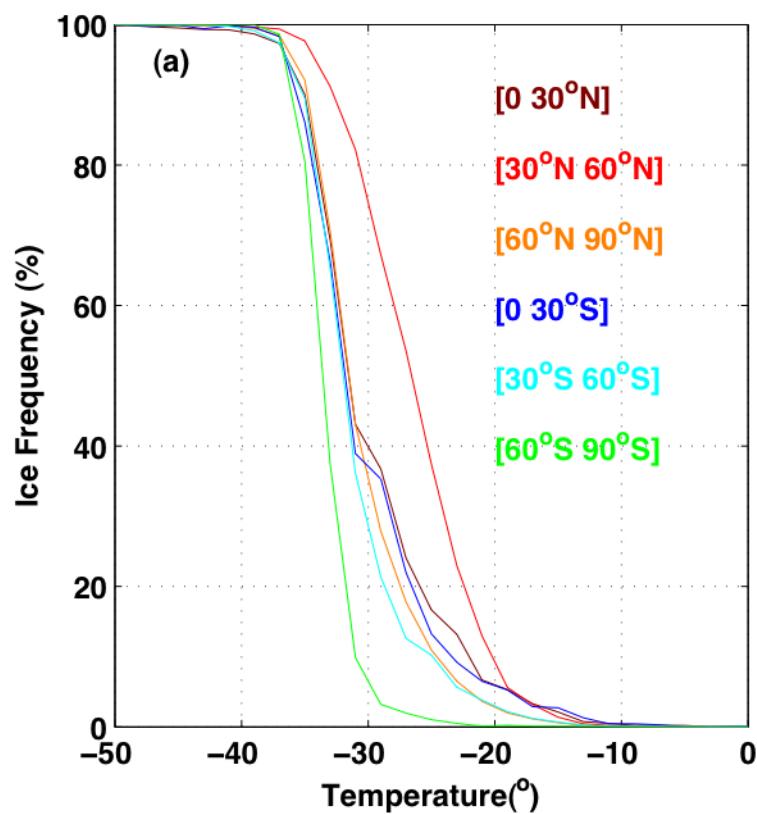


## Observed Cloud top phase dependency on temperature



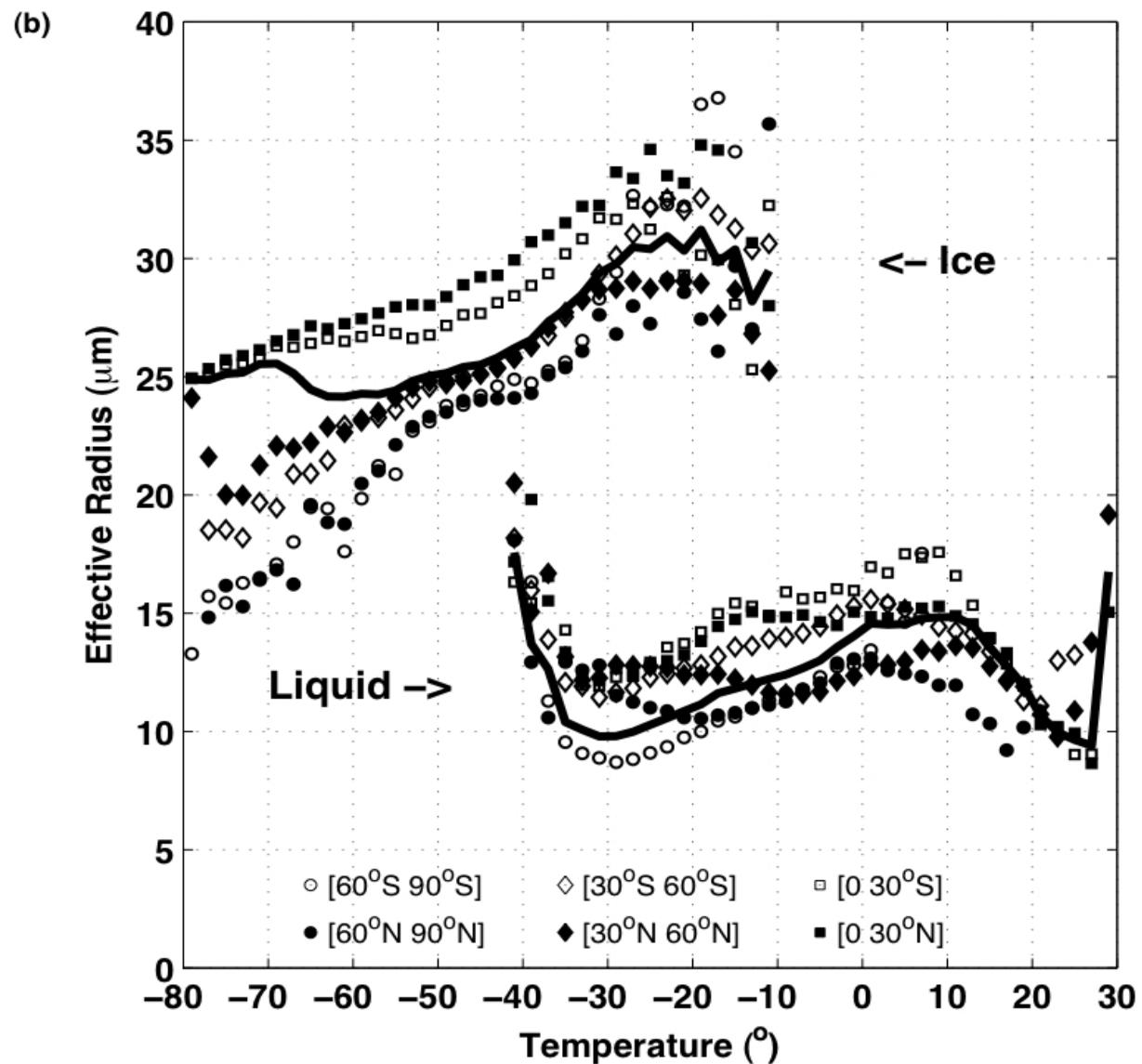
Latitudinal dependence of cloud top thermodynamic phase to cloud top temperature and the associated hyperbolic tangent functions.

# Observed Cloud top phase dependency on temperature



Latitudinal dependence of cloud top thermodynamic phase to cloud top temperature and the associated hyperbolic tangent functions coefficients.

## Observed particle effective radius dependency on temperature

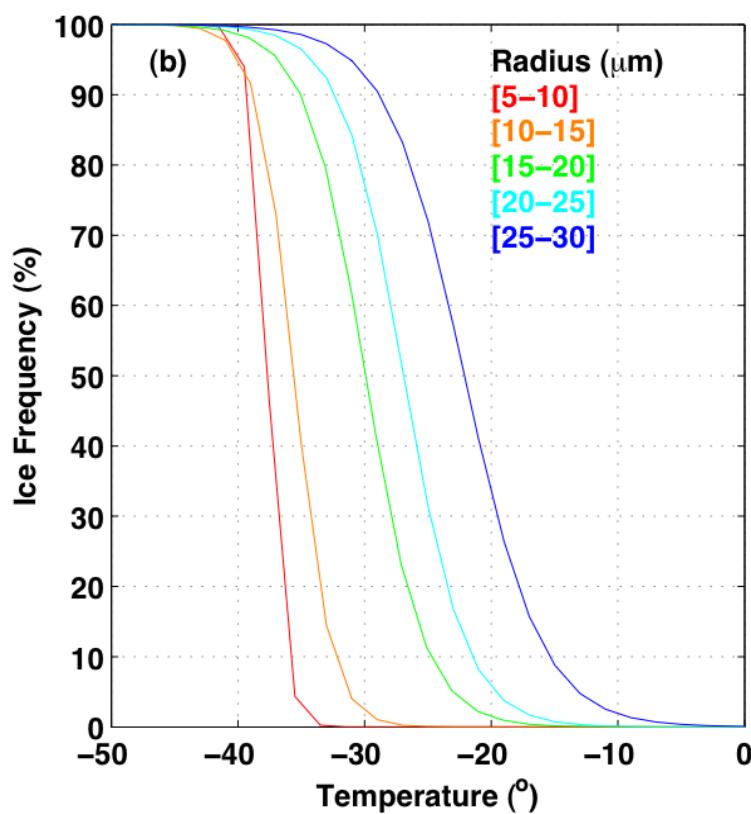
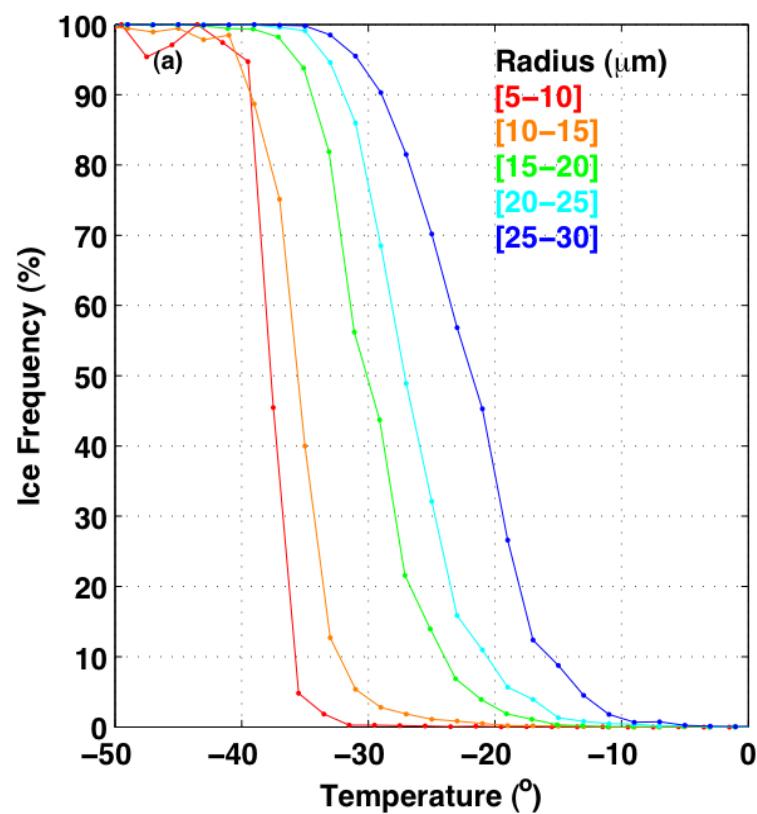


MODIS Particle size

Phase from the high  
confidence  
POLDER/MODIS  
dataset

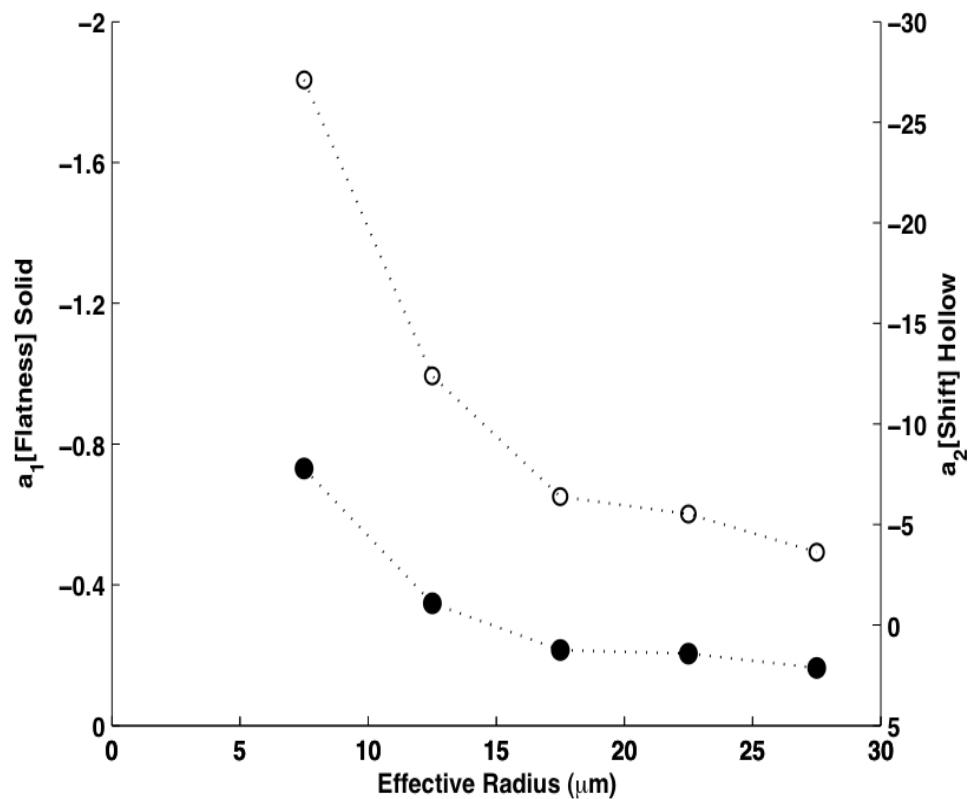
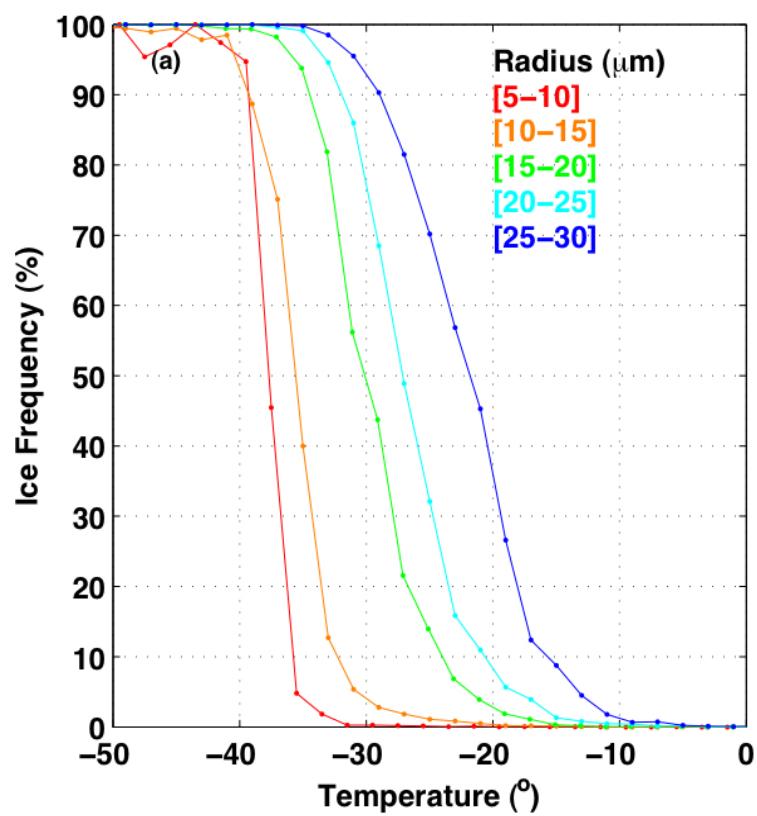
Opaque clouds and  
Cloud Top Temperature  
from CALIPSO

# Observed Cloud top phase dependency on temperature Influence of particle size



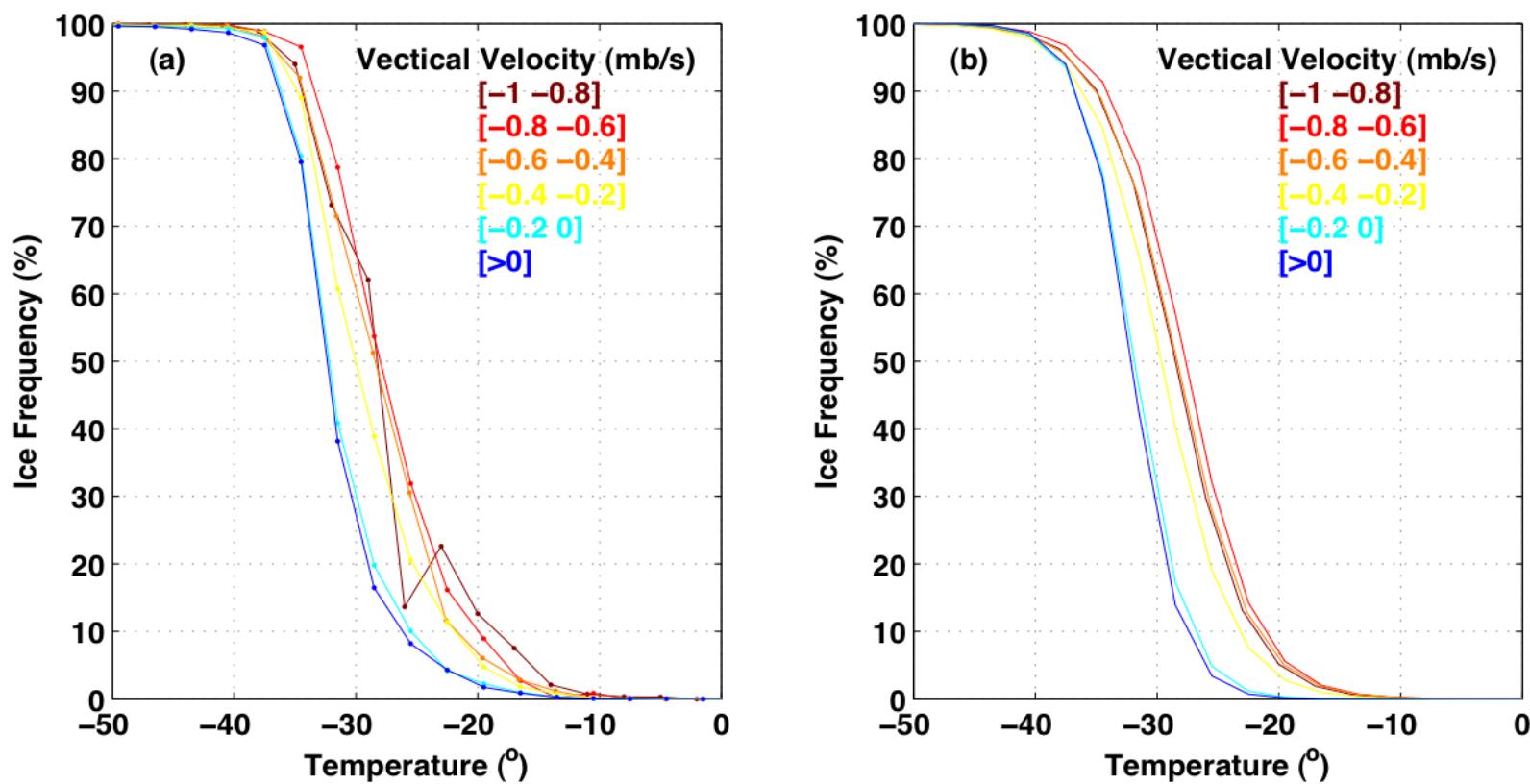
Observed dependency of cloud top thermodynamic phase to cloud top temperature for different particle size ranges and the associated hyperbolic tangent functions.

# Observed Cloud top phase dependency on temperature Influence of particle size



Observed dependency of cloud top thermodynamic phase to cloud top temperature for different particle size ranges and the associated hyperbolic tangent functions coefficients.

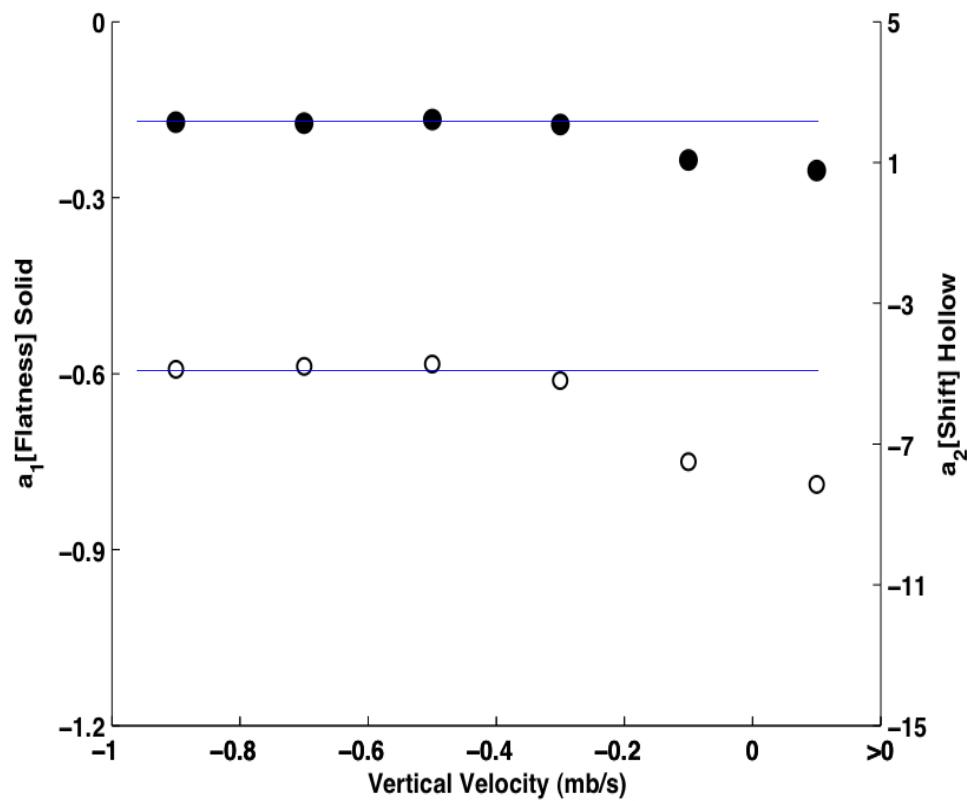
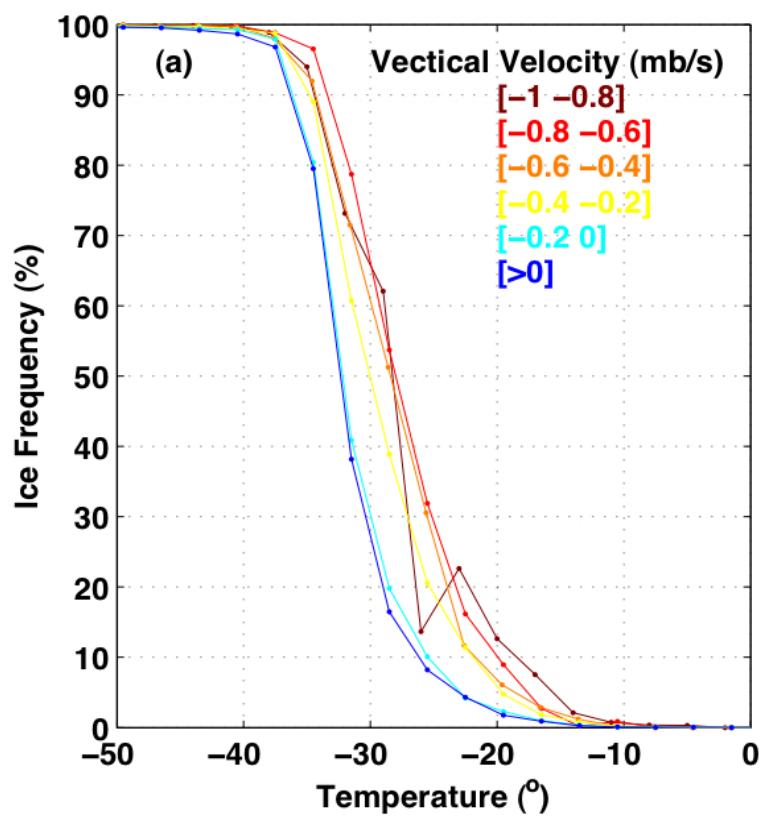
# Observed Cloud top phase dependency on temperature Impact of large scale vertical motion ?



Observed dependency of cloud top thermodynamic phase to cloud top temperature for different vertical velocity at 500hPa ranges and the associated hyperbolic tangent functions.

# Observed Cloud top phase dependency on temperature

## Impact of large scale vertical velocity ?



Observed dependency of cloud top thermodynamic phase to cloud top temperature for different vertical velocity at 500hPa ranges and the associated hyperbolic tangent functions coefficients.

# Summary

- POLDER phase product provides a reliable information on thermodynamic phase independant of cloud temperature and particle size
- In conjunction, POLDER and MODIS can be used to create a reference cloud phase dataset for benchmark studies of models or other sensors
- This reference dataset allows to study liquid-ice phase transition and the impact of microphysics and dynamics on that transition
- We observed significant particle size dependency for the liquid-ice transition. Also large scale updraft impact is observed (Naud et al, 2006)
- Future work includes (1) accounting for cloud history, (2) focusing on regional analysis, (3) evaluating potential aerosol impact on transition, (4) relating transition parameters to processes.

# Last take home message :

**Don't trust FOX news !**

**The French POLDER instrument  
has not retired yet ...**

**It just moved to a lower orbit.**

**If PARASOL is forced to retire, the space  
railway union threatens to go on strike**



# THANKS

Please visit the following posters

**Cloud fraction**

**Cloud phase**

**Cloud optical thickness**

**Cloud vertical structure**

**Aerosols above clouds**

**Arctic Aerosols/Clouds**

Parol et al (poster)

Zeng et al (poster)

Cornet et al (poster)

Ferlay et al (poster)

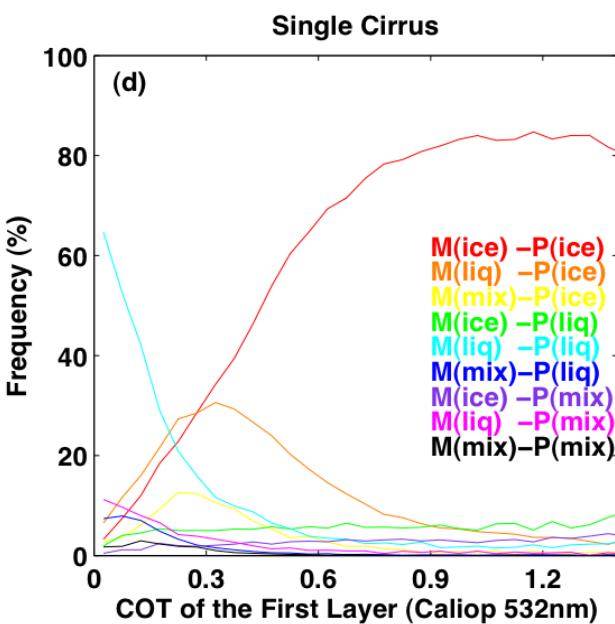
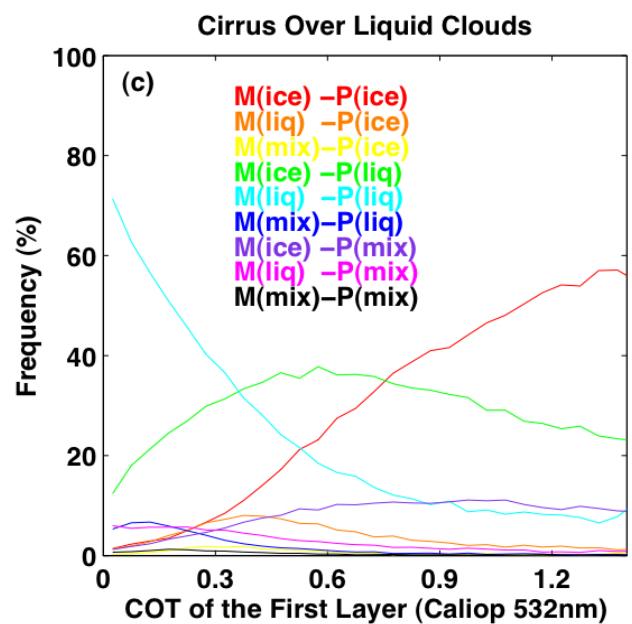
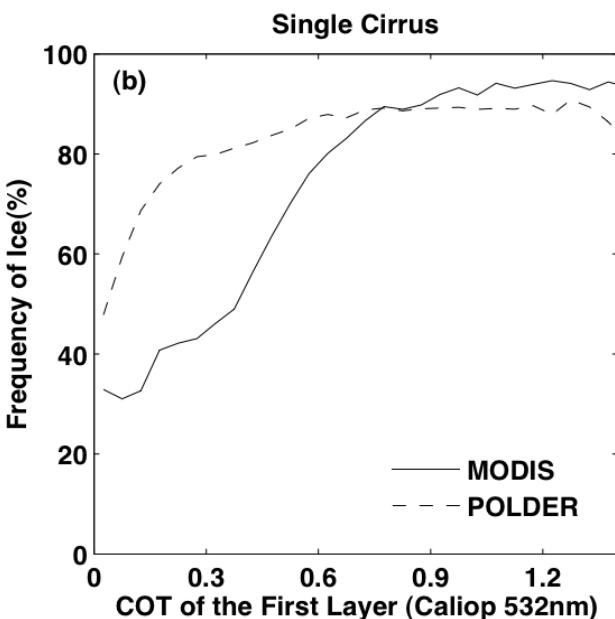
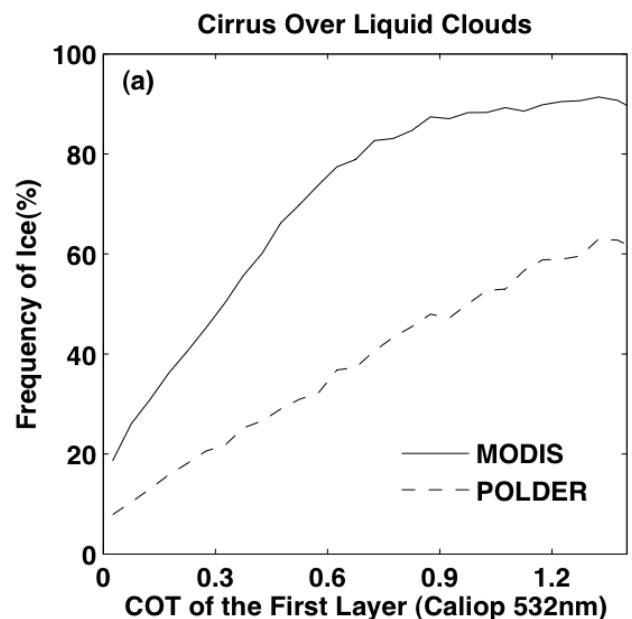
Waquet et al (poster)

Tietze et al (poster)



# Additionnal

# Sensitivity to thin cirrus



# View zenith angle analysis of Phase detection

Data: PM dataset, 12/2007-11/2008, [90°S-90°N]

